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GB 2293232 A **GB 2247521 A** **US 6018950 A**
US 5414999 A **US 3647021 A**

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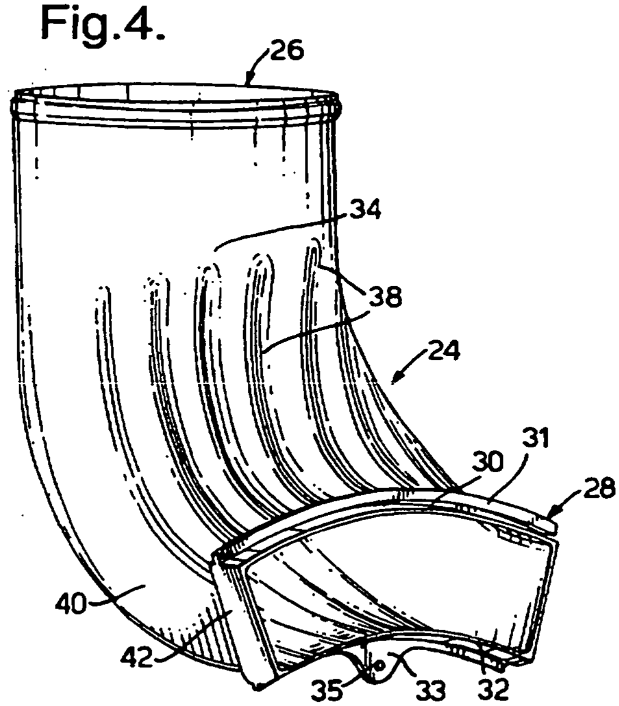
(54) Abstract Title
Discharge nozzle for a gas turbine engine combustion chamber

(57) A discharge nozzle 24 for a combustion chamber (10, figure 1) includes a hollow duct having walls of a sheet material, one or more portions 36, (34, figure 1) of the walls being provided with at least one corrugation 38. The corrugation(s) 38 allow the natural modes of vibration of the duct to be adjusted, thus preventing destructive resonance occuring.

Fig.4.



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At least one drawing originally filed was informal and the print repr duced here is taken from a later filed formal copy.

Fig.1.

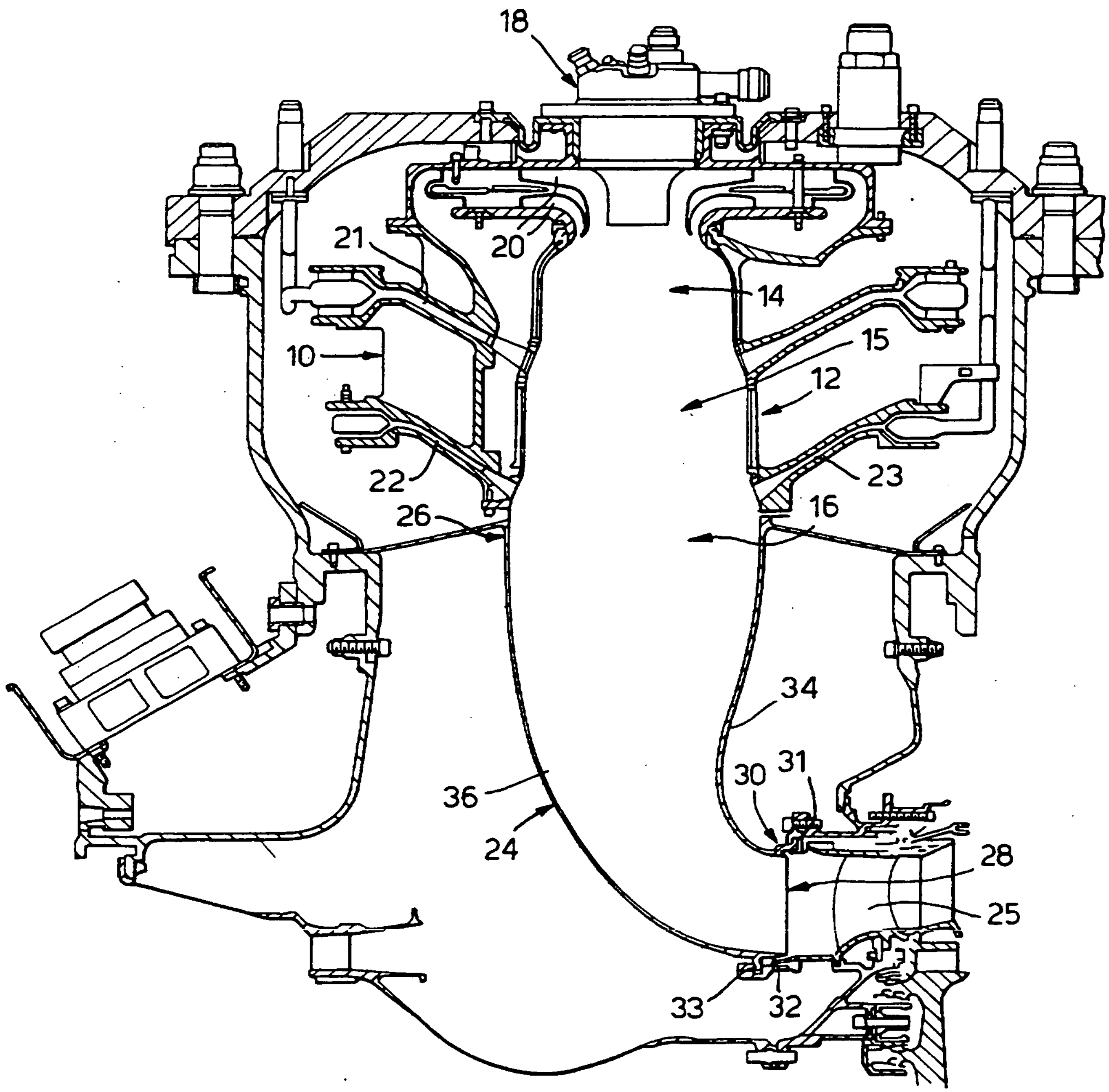


Fig.2.

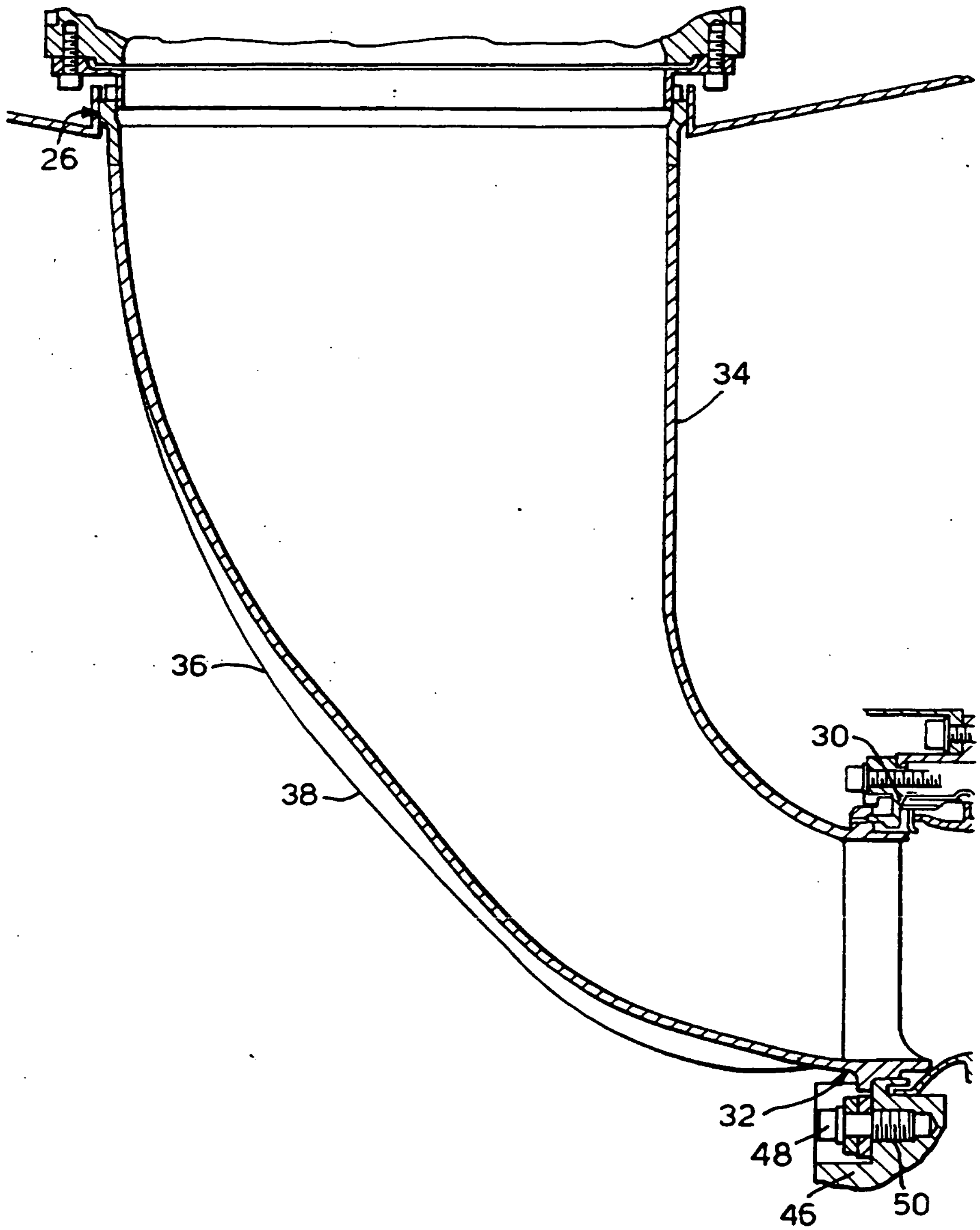


Fig.3.

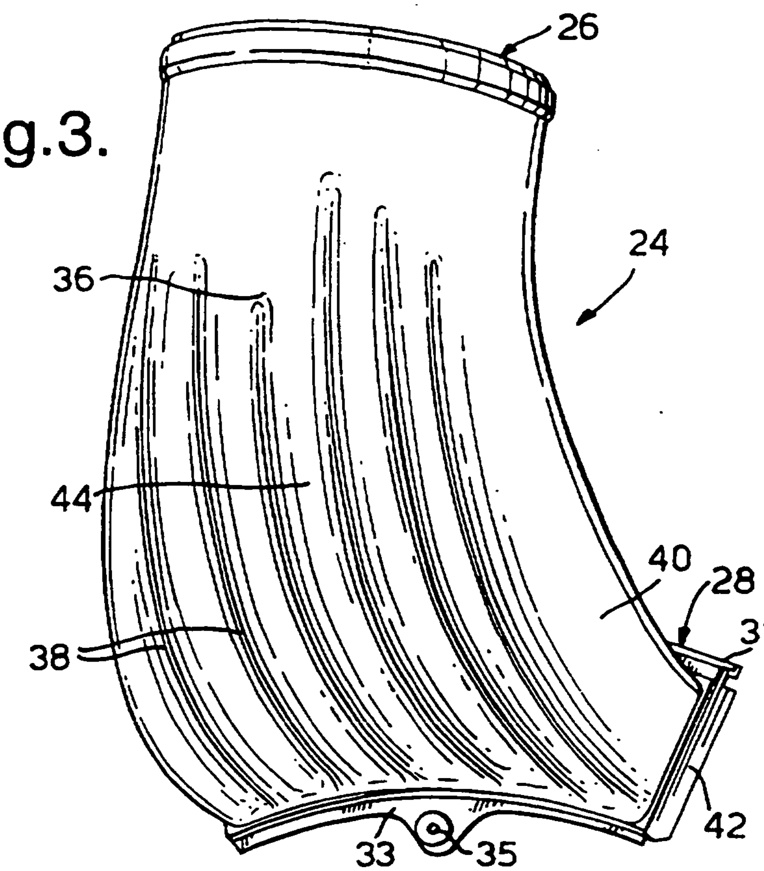


Fig.4.

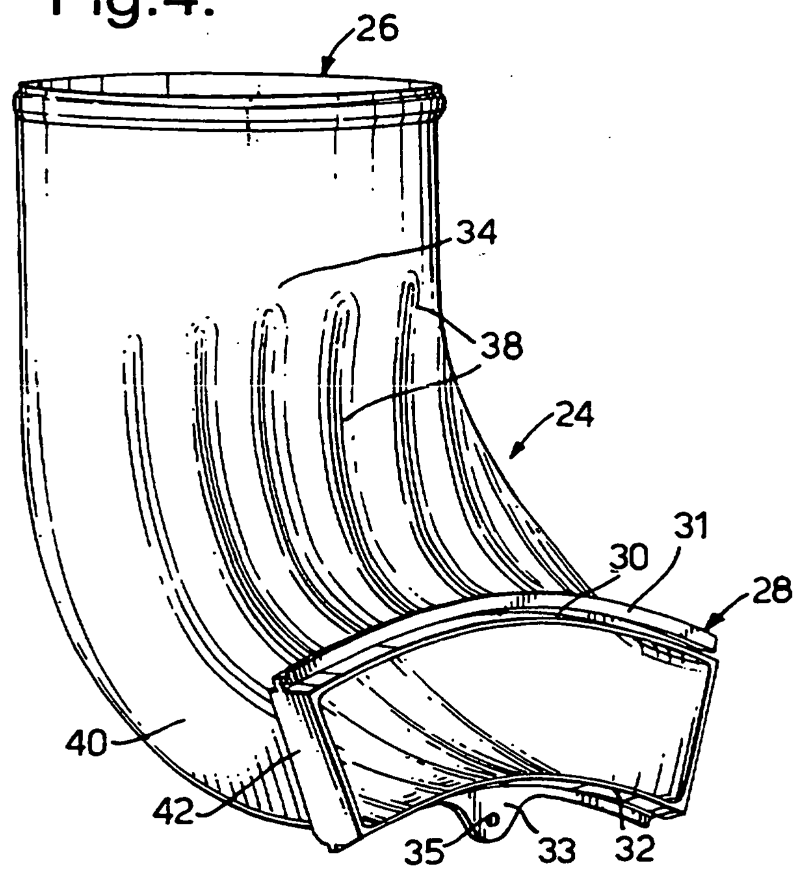


Fig.5.

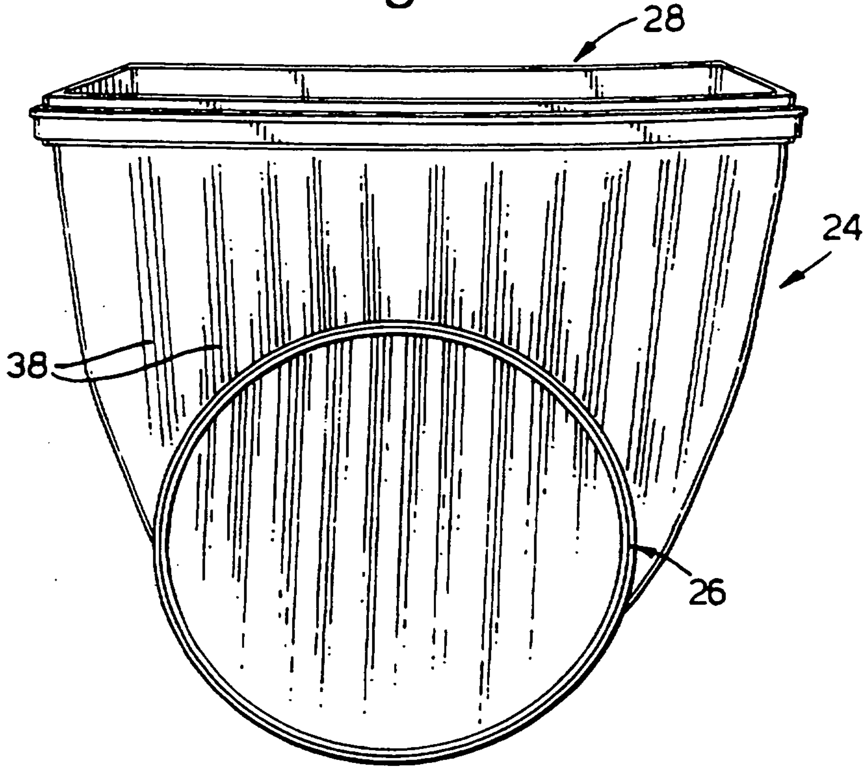
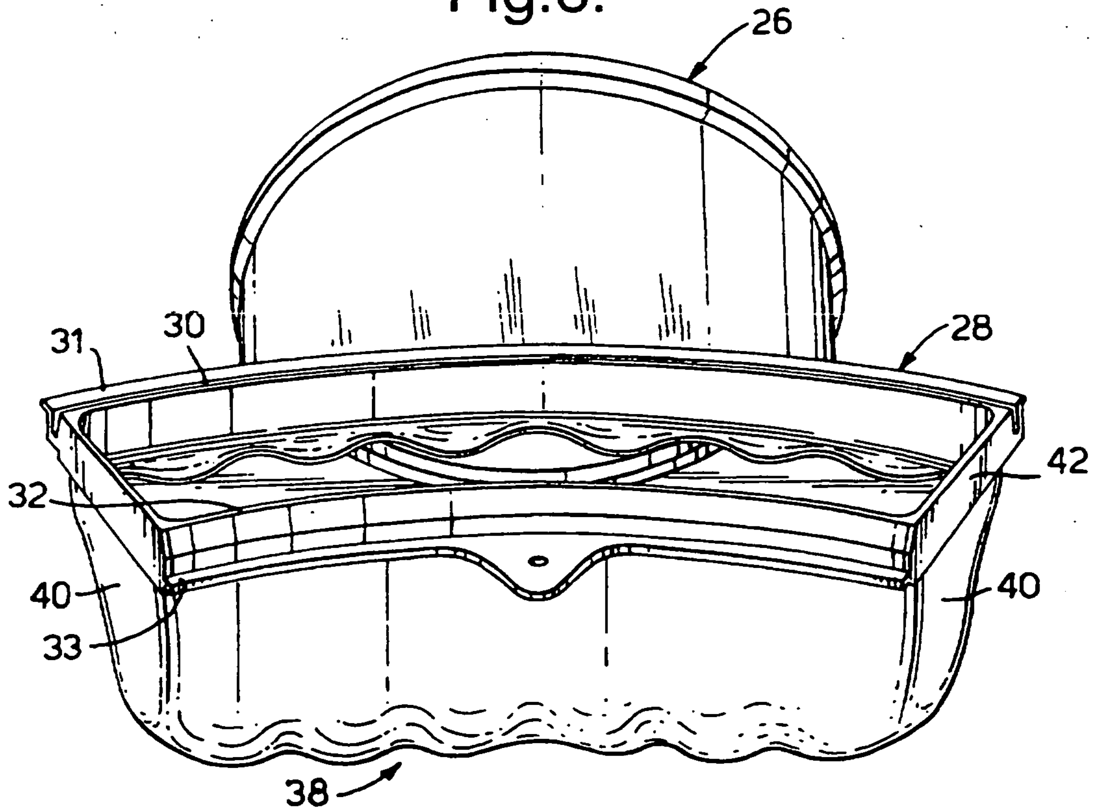


Fig.6.



Discharge Nozzle for a Gas Turbine Engine Combustion Chamber

The invention relates to a discharge nozzle for a gas turbine engine combustion chamber and particularly to a discharge nozzle for an industrial gas turbine engine combustion chamber.

Industrial gas turbine engines typically include a plurality of cylindrical or tubular combustion chambers arranged with their axes generally radially to the axis of the gas turbine engine. The emission level requirements for industrial gas turbines are extremely strict and industrial gas turbine engine combustion chambers are relatively large compared to aero gas turbine combustion chambers in order to minimise NOx and other emissions. Each combustion chamber typically has two or more stages of combustion arranged in flow series so that the products of the first combustion stage flow into the second combustion stage, etc. Fuel is usually supplied into each of the combustion stages, the fuel for each stage being thoroughly premixed with the combustion air in an associated mixing duct. The thorough mixing of the fuel and air enables the fuel to be burnt at lean fuel to air ratios, less than stoichiometric, minimising the temperature of combustion and hence the emissions. In order to meet the emissions requirements, it is also necessary with current design technology that the combustion process be relatively turbulent. In general, the more turbulent the combustion process, the lower the emissions that are generated.

The turbulence within the combustion chamber results in noise, which can have damaging effects. The noise generated loads have proved particularly destructive to the "discharge nozzle" that carries and turns the combustion air from the radial combustion chambers into the high pressure turbine nozzle guide vanes. Certain of the

vibration frequencies emanating from the combustor coincide with natural "panel" modes of vibration of the discharge nozzle, resulting in significant vibration and eventual destruction of the discharge nozzle.

According to the invention there is provided a discharge nozzle for a combustion chamber, the discharge nozzle including a hollow duct comprising at least one wall, one or more portions of the wall being provided with at least one corrugation.

Preferably at least one portion of the wall is provided with a plurality of corrugations.

Preferably the duct is elongate and the corrugation(s) are oriented substantially in an axial direction of the duct.

The corrugation(s) are preferably provided on a portion of the duct which has the least curvature.

Preferably corrugations are provided on a front portion of the duct. Corrugations may also be provided on a back portion of the duct. Side portions of the duct, located between the front and back portions, are preferably not provided with corrugations.

The duct may include a substantially circular inlet end for receiving air from the combustion chambers and an exit end through which air exits from the discharge nozzle.

Preferably the corrugations do not extend to the inlet end or the exit end.

Preferably the amplitude of the corrugation(s) is greatest in a central region of the front and/or back portions of the duct and decreases towards the inlet end and the outlet end.

Preferably the duct is curved, such that the general plane of the inlet end is oriented at an angle to the general plane of the outlet end.

The exit end may include a front edge lying on an arc of a circle, a back edge lying on an arc of a smaller circle, and side edges joining the front and back edges.

The front portion of the duct may extend between the inlet end and the front edge of the exit end and the back portion of the duct may extend between the inlet end and the back edge of the exit end. The side portions of the duct may extend between the inlet end and the side edges of the exit end.

The front portion of the duct and the back portion of the duct may have respectively different natural resonant frequencies of panel mode vibration. Preferably neither the front portion or the back portion of the duct have significant natural resonant frequencies of panel mode vibration in the 250Hz-800Hz range.

The portions of the walls of the discharge nozzle may be of sheet material.

According to the invention there is also provided combustion apparatus including a combustion chamber and a discharge nozzle as defined in any of the preceding nine paragraphs. The combustion apparatus may be for use in a gas turbine engine, which may be an industrial gas turbine engine.

According to the invention there is further provided a gas turbine engine including a plurality of combustion apparatus as defined in the preceding paragraph. Preferably the combustion chambers are arranged substantially radially in relation to a general axis of the gas turbine engine. Preferably exit ends of the discharge nozzle ducts are connected together by a floating ring.

An embodiment of the invention will be described for the purpose of illustration only with reference to the accompanying drawings, in which:-

Fig. 1 is a sectional view of a prior art combustion apparatus, illustrating the position of the discharge nozzle;

Fig. 2 is a sectional view of the discharge nozzle according to the present invention;

Fig. 3 is a diagrammatic perspective view of the

discharge nozzle of Fig. 1, generally from the rear of the nozzle;

Fig. 4 is a diagrammatic perspective view of the discharge nozzle of Fig. 1, generally from the front of the nozzle;

Fig. 5 is a diagrammatic top view of the discharge nozzle of Fig. 1; and

Fig. 6 is a diagrammatic view of the discharge nozzle of Fig. 1, viewed generally from the rear of the nozzle.

Referring to Fig. 1, a combustion chamber assembly 10 for an industrial gas turbine engine includes a plurality of equally circumferentially spaced tubular combustion chambers 12 (one of which is illustrated in Fig. 1). The axes of the tubular combustion chambers 12 are arranged to extend generally in radial directions relative to the main axis of the gas turbine engine. The inlets of the tubular combustion chambers 12 are at their radially outermost ends and the outlets are at their radially innermost ends. Each combustion chamber includes primary, secondary and tertiary combustion zones 14, 15 and 16 respectively. Fuel is supplied to the combustion zones through a central injector 18 and through primary, secondary and tertiary ducts 20, 21 and 22.

Located radially inwardly of the combustion chamber 12 is a discharge nozzle 24, which carries and turns the combustion gases from the combustion chamber 12 to high pressure turbine nozzle guide vanes 25 located downstream of the combustion chamber assembly. The discharge nozzle 24 consists of an elongate duct which is angled so as to turn the combustion gases through approximately 90°.

An inlet end 26 of the discharge nozzle 24 is substantially circular in section. An exit end 28 of the discharge nozzle includes a front edge 30 lying on an arc of a circle and a back edge 32 lying on an arc of a smaller circle. The front edge includes a protruding mounting flange 31 and the back edge includes a protruding mounting

flange 33. The front edge 30 and the back edge 32 are joined by side edges 42. The general shape of the exit end 28 of the discharge nozzle 24 may be seen more clearly in Fig. 4, which illustrates a discharge nozzle 24 according to the invention.

The cross sectional shape of the discharge nozzle 24 gradually changes from circular (at the inlet end 26) to a section of an annulus (at the exit end 28).

The discharge nozzles 24 of adjacent combustion chambers 12 are arranged such that the side edges 42 of their respective exit ends 28 lie next to one another. Together the exit ends 28 of the discharge nozzles 24 from all the radial combustion chambers 12 form a substantially annular outlet. This results in an annular flow of gases from the combustion chambers, which is similar to the flow of gases which would be produced by the annular combustion chamber of an aero gas turbine engine.

Each discharge nozzle 24 includes a front portion 34 extending generally between the front edge 30 of the exit end 28 and the inlet end 26. A back portion 36 extends generally between the back edge 32 of the exit end 28 and the inlet end 26. The discharge nozzle 24 also includes side portions 40 extending generally between side edges 42 of the exit end 28 and the inlet end 26.

The discharge nozzles 24 are subject to certain problems caused by turbulence in the combustion chamber. This turbulence causes vibrations, some of which have frequencies corresponding to the natural "panel mode" vibrational frequencies of the discharge nozzle 24. The panel modes of vibration correspond to vibration inwardly and outwardly of relatively flat parts of the discharge nozzle 24 generally located within the front portion 34 and back portion 36. Such panel modes might occur for example at about 530 Hz. Eventually, the vibration may cause the destruction of the discharge nozzle 24. The vibration also causes "fretting" at the edges of the discharge nozzle 24,

which eventually causes destruction of the mounting points.

Referring to Figs. 2 to 6, a discharge nozzle 24 according to the invention includes a plurality of ripples or corrugations 38 on its front portion 34 and on its back portion 36. The side edges 42 are not provided with ripples.

The ripples 38 extend generally in an axial direction of the discharge nozzle 24, or longitudinally between the inlet end 26 and exit end 28 of the discharge nozzle 24.

Referring particularly to Fig. 3, the ripples 38 on the back portion 36 of the discharge nozzle 24 do not extend right up to the inlet end 26, but "fade out" in a radially outer region of the discharge nozzle 24. Likewise, the ripples 38 do not extend right to the exit end 28 of the discharge nozzle 24 but also fade out in this region. The amplitude of the ripples is greatest in a central region 44 of the back portion 36 of the discharge nozzle 24. The fading out takes the form of a gradual decrease in the amplitude of the ripples 38 towards the ends 26 and 28 of the discharge nozzle 24. The ripples 38 also fade out towards the side portions 40 of the discharge nozzle 24. Again, the fading out takes the form of the amplitude of the ripples 38 being greatest in a central region 44 of the back portion 36 of the discharge nozzle and gradually decreasing towards the side portions 40.

Referring to Fig. 4, the ripples 38 provided on the front portion 34 of the discharge nozzle 24 also fade out towards the inlet end 26 and the exit end 28 of the discharge nozzle 24, and towards the side portions 40 of the discharge nozzle 24.

Referring particularly to Fig. 6, the profile of the ripples 38 is approximately semi-circular when the ripples 38 are at their deepest. As the ripples fade out, they represent increasingly small arcs of a circle, the circle always having substantially the same radius.

There may be, for example, between about one and

twenty ripples on each of the front and back portions 34 and 36.

The effect of the ripples 38 is to alter the frequencies of the discharge nozzles' natural modes of vibration, particularly the principal panel modes that are present on the front and back portions 34 and 36 of the discharge nozzle 24. For example, there has been found to be a particularly destructive mode of vibration between 400 Hz and 600 Hz. By rippling the discharge nozzle 24, its natural frequencies of vibration may be moved out of this frequency band range. The ripples 38 also allow the alternating vibration stress levels to be reduced for a given magnitude of "noise". The ripples 38 further allow the natural mode shapes to be controlled such that areas of peak distortion are moved away from areas that are particularly vulnerable to peak stress crack initiation, generally end surfaces and seal/mounting flanges. The ripples 38 also increase the general stiffness of the discharge nozzle walls, reducing its response to vibration, at all frequencies.

In general, the greater the depth of the ripple 38, the higher the natural mode of vibration of the area in question, although the effect is asymptotic. The ripple profile may thus be adjusted to move the principal modes of vibration to relatively safe frequencies, or to reduce the alternating stress response to acceptable levels.

Various aerodynamic considerations must be balanced against the desire to increase the natural vibrational frequencies. Firstly, the ripples 38 are faded out towards the exit end 28 of the discharge nozzle 24, in order that the air leaving the discharge nozzle 24 flows as smoothly as possible. In general, the airflow should be as similar to the airflow from an aero engine combustion chamber as possible, in order to avoid unpredictable effects. Similarly, the fading out of ripples 38 towards the side portions 40 of the discharge nozzle 24 helps to keep the

flow generally smooth. Internal aerodynamic considerations are likely to impose a restraint on the maximum depth of ripple 38 available. With the internal airflow it is important that the hot gases are not allowed to become detached from the discharge nozzle profile, as a sudden point of reattachment could result in the burning of the nozzle. This may alter cooling issues and must be taken into account when designing the ripple profile.

Referring to Fig. 2, the profile of the back portion 36 of the discharge nozzle 24 in a region near the radially inner edge 28, is modified to improve the airflow. The radius of curvature of the back portion 36, adjacent to the back edge 32 of the exit end 28 is greater than that of the prior art discharge nozzle illustrated in Fig. 1. This creates a double ripple in two different planes.

A further contribution towards the shifting of the vibrational frequencies and the reduction of vibrational amplitudes is the mounting of the exit end 28 of the discharge nozzle 24. According to the invention, the exit ends 28 of the respective discharge nozzles 24 of the tubular combustion chambers are linked together, via an inter discharge nozzle mounting ring 46. The mounting flange 33 of each discharge nozzle 24 has an aperture 35 to enable the discharge nozzle 24 to be fastened to the ring 46 by a bolt 48 which locates in a threaded aperture 50 in the ring 46.

The ring 46 is fully floating but, because the vibrations of the respective discharge nozzles 24 do not tend to coincide, linking their radially inner edges 28 together significantly reduces those vibrations. Because the ring 46 is fully floating, it imposes only very limited thermal stresses onto the discharge nozzles 24, from the movement of their respective counterparts. The ring 46 should sit at the same temperature as that of the discharge nozzle mounting components and, when made of a similar material, should expand at the same rate to move out with

the discharge nozzles 24. The ring 46 may be made as rigid as required, in order to restrain the discharge nozzles' movement both radially and tangentially at the central lug position. This modifies the vibration modes of each discharge nozzle 24, resulting in rolling at the position of fastening, by the bolt 48 and aperture 35, of the discharge nozzle 24 to the ring 46.

There is thus provided a discharge nozzle 24 in which rippling 38 may be used to move the natural vibrational frequencies up into regions where they are not significantly excited by the airflow from the combustion chamber 12. The general stiffness of the discharge nozzle 24 is also increased, such that its response to any vibrational stimulus is decreased. The stiffness is increased without requiring an increase in wall thickness of the discharge nozzle 24, which can have associated cooling problems. The use of the ripples 38 may help the transition from turbulent counter-swirling gases (exiting the combustion chamber 12), to a smooth flow of gases to be conveyed to the high pressure turbine.

The discharge nozzle may be manufactured relatively straightforwardly by cold pressing wrought alloy sheets to form the front, back and side portions and casting alloy to form the inlet and exit ends.

Whilst endeavouring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.

Claims:-

1. A discharge nozzle for a combustion chamber, the discharge nozzle including a hollow duct comprising at least one wall, one or more portions of the wall being provided with at least one corrugation.

2. A discharge nozzle according to claim 1 wherein at least one portion of the wall is provided with a plurality of corrugations.

3. A discharge nozzle according to claim 1 or claim 2 wherein the duct is elongate and the corrugation(s) are oriented substantially in an axial direction of the duct.

4. A discharge nozzle according to any preceding claim wherein the corrugation(s) are provided on a portion of the duct which has the least curvature.

5. A discharge nozzle according to any preceding claim wherein corrugations are provided on front and back portions of the duct.

6. A discharge nozzle according to claim 5 wherein side portions located between the front and back portions are not provided with corrugations.

7. A discharge nozzle according to any preceding claim wherein the duct includes a substantially circular inlet end for receiving air from the combustion chamber and an exit end through which air exits from the discharge nozzle.

8. A discharge nozzle according to claim 7 wherein the corrugations do not extend to the inlet end or to the exit end.

9. A discharge nozzle according to claim 8 wherein the amplitude of the corrugation(s) is greatest in a central region of the front and/or back portions of the duct and decreases towards the inlet end and the exit end.

10. A discharge nozzle according to any of the claims 7 to 9 wherein the duct is curved, such that the general plane of the inlet end is oriented at an angle to the general plane of the exit end.

11. A discharge nozzle according to claim 10 wherein the exit end includes a front edge lying on an arc of a circle, a back edge lying on an arc of a smaller circle, and side edges joining the front and back edges.

12. A discharge nozzle according to claim 11 wherein a front portion of the duct extends between the inlet end and the front edge of the exit end and a back portion of the duct extends between the inlet end and the back edge of the exit end.

13. A discharge nozzle according to claim 12 wherein the front portion of the duct and the back portion of the duct have respectively different natural resonant frequencies of panel mode vibration.

14. A discharge nozzle according to claim 12 or claim 13 wherein neither the front portion or the back portion of the duct have significant natural resonant frequencies of panel mode vibration in the 250Hz-800Hz range.

15. A discharge nozzle according to any preceding claim wherein the portions of the wall of the discharge nozzle are of a sheet metal.

16. Combustion apparatus including a combustion chamber and a discharge nozzle according to any preceding claim.

17. A gas turbine engine including a plurality of combustion apparatus according to claim 16, arranged substantially radially in relation to the general axis of the gas turbine engine; wherein the exit ends of the discharge nozzle ducts are connected together by a floating ring.

18. A discharge nozzle substantially as herein described with reference to Figs. 2 to 6 of the drawings.

19. A combustion apparatus substantially as herein described with reference to Figs. 2 to 6 of the drawings.

20. Any novel subject matter or combination including novel subject matter disclosed herein, whether or not within the scope of or relating to the same invention as any of the preceding claims.

The Patent Office 12

Application No: GB 0008959.9 **Examiner:** Rhys Williams
Claims searched: 1-19 **Date of search:** 6 October 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): F4T (TAS, TAR1, TAR3, TAR5, TAR6) F1T (TFDA)

Int Cl (Ed.7): F01D (9/02) F23R (3/34, 3/42, 3/44, 3/46, 3/48, 3/60)

Other: On-line: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2293232 A	(ROLLS-ROYCE) See figure 2.	-
A	GB 2247521 A	(ROLLS-ROYCE) See figure 2.	-
X	US 6018950	(MOELLER) See the figures,	1-5, 7, 8, 10-12 and 15-17
A	US 5414999	(BARNES) See figure 3.	-
X	US 3647021	(MILLMAN) See figure 1.	1-3, 5 and 7

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
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